Before the
Federal Communications Commission
Washington, DC 20554

In the matter of	)	
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Mitigation of Orbit Debris	)	IB Docket No. 02-54
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	)	

To: The Commission

COMMENTS OF THE RADIO AMATEUR SATELLITE CORPORATION

1. The Radio Amateur Satellite Corporation (hereinafter referred to as "AMSAT®"), pursuant to Section 1.405 of the Commission's Rules and Regulations, respectfully submits these comments in response to the Commission's Notice of Proposed Rule Making, IB Docket No. 02-54, released March 18, 2002.

2. AMSAT commends the Commission for initiating this Proceeding. The increasing quantity of space debris presents a potential problem to all who wish to use space. In view of the damage that can be caused by such debris and its current rate of increase, especially in near-Earth orbit, AMSAT agrees that methods of controlling and reducing it are called for.

3. Accordingly, AMSAT is pleased to offer technical comments regarding the nature of the rules that might be adopted as well as respond to some of the questions raised in the NPRM. Further, comments will be made regarding some state-of-the-art of technologies of which AMSAT has recently become aware, that may offer the potential for de-orbiting spacecraft once their missions have ended.

4. AMSAT will also comment regarding special considerations which it contends must be taken into account in framing any new rules specifically affecting spacecraft built and launched in support of the amateur-satellite service.

I. PRELIMINARY STATEMENT

5. AMSAT was founded in 1969 and chartered in the District of Columbia. It is recognized by the Internal Revenue Service as a 501(c)(3) entity. In its over 33 years of existence, AMSAT has been involved in the construction, testing, launch and operation of ten amateur radio satellites, the latest being Phase 3D, now renamed AMSAT-OSCAR-40 (AO-40).

II. BACKGROUND

A. Technical and Scientific Aspects of the Orbital Debris Problem

6. In the NPRM the Commission correctly states, "Atmospheric drag on orbiting objects decreases dramatically as the orbital altitude of the object increases."[1] The Commission also notes that the lifetime of space objects is affected by solar activity. AMSAT wishes to also point out that a space object's lifetime is also a function of its mass divided by its projected surface area. This ratio is generally known as the object's *ballistic coefficient.* Lower values of ballistic coefficient will result in a decreased lifetime caused by a higher effective drag acting on an object orbiting at any given altitude.[2] Novel, innovative methods of taking advantage of this property, not requiring on-board propulsion, may prove to be helpful in providing a practical method of de-orbiting spacecraft following their end of life.

B. Development of U.S. Policy and Regulations Concerning Orbital Debris

7. AMSAT supports the intent of the first three objectives developed under U.S. Governments Standards and Practices for the control of debris.[3] However, it must be stressed that, as a practical matter, objective 2 (minimizing debris generated by accidental explosions) is unlikely to be met by additional failure mode analysis. No organization building spacecraft desires an accidental explosion, and thus makes every effort to avoid any such undesirable incident. Therefore, AMSAT

[1] NPRM at §7.
[2] Wertz, J.R. and Larson, W.J., "Space Mission Analysis and Design," Fig. 8-4, Space Technical Library, 1999, p 210.
[3] NPRM at §11

questions whether significant changes in the quantity of debris generated through accidental explosions will result from the imposition of any additional review requirements of this nature. AMSAT, though agreeing with the Commission's interest expressed in Paragraph 37 of the Notice dealing with collisions with man-made objects, takes strong exception when it comes to meteors. Any organization launching satellites will attempt to access the orbital parameters of known objects, and make every effort to avoid collisions with them. This is akin to efforts made to avoid accidental explosions. However, no such information is available for meteors. Thus, any analysis with respect to them is beyond anyone's capability.

8. In light of the above, AMSAT's comments in this proceeding will primarily be related to the Commission's objective of providing for disposal of space structures upon completion of their missions.

C. International Aspects

9. AMSAT appreciates the role the FCC can play in the enforcement of the Outer Space Treaty and related international agreements with respect to controlling orbital debris. The Commission's activity, in cooperation with the NTIA and the Department of State, concerning spectrum utilization issues has a long record of successful interaction with administrations of other countries to represent the interests of both the U.S. Government and our country's private sector. Also, the Commission's role in working at the ITU has brought significant benefit to both the public and the private sectors. Accordingly, AMSAT understands the Commission's intent for an extension of this role for the purpose discussed in the NPRM.

III. DISCUSSION

A. FCC Statutory Authority Concerning Orbital Debris

10. In the Notice, the Commission seeks public comment as to its authority to establish policy for and regulate the generation and elimination of orbital debris.[4] AMSAT sees this as a legal and policy issue which is beyond its ability to comment. Nevertheless, the organization feels this added responsibility would be a natural role for the Commission to assume and the approach proposed in the NPRM would be far superior to many other options which might otherwise be selected. In particular, it will avoid the requirement for parties desiring to launch satellites to obtain yet one more license from yet another Government agency. A radio license from the FCC is already required for all non-government space systems. In the case of amateur radio satellites, this can be any FCC licensed amateur, and that individual is responsible for the operation of that specific space station. Presumably, that individual would become responsible for meeting whatever orbital debris requirements the Commission might decide to include in Part 97 of the Rules.

11. In the Notice, the Commission seeks comment on whether there are matters involving launch vehicles that FCC has authority to consider.[5] AMSAT wishes to bring to the Commission's attention the fact that the upper stages of launch vehicles are frequently placed into quasi-stable or even stable orbits. In may cases, stages that are injected into geostationary transfer orbit (GTO) which, because of their low perigees, will typically re-enter the atmosphere nine months to one year after entering orbit. However, the upper stages of launch vehicles going to sun-synchronous orbits, for example, remain in virtually the same orbit as the spacecraft itself. Such orbits can be stable for hundreds to thousands of years. Sometimes attempts are made, when residual fuel exists, to reduce the perigee of these spent stages and thus cause them to re-enter. However, this is not always an option. AMSAT suggests that it would be more efficient for a single agency of the Government to address

[4] NPRM at §30
[5] NPRM at §32

the orbital debris, rather than dividing the responsibility between two agencies (the FCC for the spacecraft and the FAA, for example, for the launch vehicle). However, AMSAT is not in a position to make specific recommendations as to how this might be accomplished. It is also true that upper stages frequently carry secondary payloads and experiments that transmit in the radio spectrum. A number of amateur radio satellites have been of this type. This, of course, implies that such an upper stage would become a more direct concern of the Commission than of another agency.

B. Elements of Orbital Debris Mitigation

12. In the Notice, the FCC seeks general comments regarding the economic impact of the adoption of debris mitigation procedures on the operation of commercial spacecraft.[6] AMSAT, being a noncommercial, not-for-profit organization, is not an operator of commercial satellites. Nevertheless, it wishes to impart some information, which it has recently become aware, particularly applicable to systems and constellations employing orbits below 900 km. Low cost technologies have recently been announced which may enable spacecraft operators to meet the Commission's 25 year criterion for orbit removal as suggested in the NRPM.[7] AMSAT believes, therefore, that it may be practical to comply with reasonable rules which the Commission may adopt in this regard. It is understood that this technology may be relatively inexpensive and thus might be applicable for satellites with perigees in this range, even for noncommercial spacecraft such as those generally used in the amateur-satellite service. Nevertheless, since this technology is new, and yet to be demonstrated, it cannot be counted on to serve until more information becomes available.

13. The Notice observes the emergence of very small satellite designs and seeks comments on whether such systems call into question the adequacy of economic incentives alone.[8] AMSAT believes this issue is a particularly important consideration in these proceedings. AMSAT is among the pioneers of the small satellite movement. In fact, the organization should be credited with

[6] NPRM at §35
[7] NPRM at §12
[8] NPRM at §38

founding it. The four MICROSATs which AMSAT designed and built, some in cooperation with amateur satellite groups from other countries, were launched in 1990. Some of them are still performing. Thus, AMSAT contends that the use of a number of very small spacecraft to provide a verity of types of communication, and conduct research on space environments must be acknowledged.

14. Both reliability and capacity enhancement can be addressed simultaneously by increasing the number of such small satellites. Further, the overall construction costs for the space segment can be minimized through "mass production" techniques. As earlier stated, AMSAT built four essentially identical structures in 1990, though some of the electronics in each differed from one another. Various methods of launching an entire constellation of very small satellites with a single, low cost, launch vehicle have been developed, making them even more economically attractive.

15. Unfortunately, the advantages of the use of many small spacecraft run counter to the objective of minimizing the quantity of space debris. The number of spacecraft that optimize some communications scenarios could run in the thousands, and their size might well be small enough to make observation by ground-based radar difficult. Since the unit cost of such spacecraft must be very low, they cannot practically be expected to include a propulsion system to affect removal from orbit. Additionally, many such spacecraft do not include an attitude control system accurate enough to orient them such that a propulsion system could be certain to cause re-entry.

16. The only means AMSAT can conceive of for removing spacecraft of this size class and in this quantity from orbit is to limit the allowable altitude of their constellations to that which would guarantee atmospheric re-entry within a specified period of time. It is noted that it is the combination of the spacecraft's perigee altitude and its ballistic coefficient that determines its orbital lifetime. Were such spacecraft required to have de-orbiting capability, which might result, in practice, in their

being prohibited entirely. AMSAT recommends that the costs and benefits of such policy options be given further study by the Commission and other interested parties.

17. The Commission seeks comment regarding whether it should change its rules and practices regarding spacecraft flight profiles.[9] AMSAT feels that rules requiring applicants to provide orbital information (such as the orbital elements for each space station) are generally helpful. For example, should particular LEO orbits become very popular and so become populated by a large number of spacecraft, it would assist spacecraft system operators planning new missions, if a data base detailing this required information were publicly accessible. AMSAT notes, however, that current state-of-the-art practices do not allow specification of the Keplerian orbital elements of spacecraft with sufficient accuracy to predict or avoid the collision of two space objects. The Keplerian elements for any space object along with a time specify where an object is in space at that particular epoch. It is then possible to *propagate* these elements forward in time to predict where the same object will be in the future. This is, however, not a completely precise science. Errors in propagating the object's elements can well result in errors large enough to render it impossible to accurately forecast a collision. It is possible to determine that two objects will pass quite close to one another, however. So, while orbital information may be useful in planning so as to minimize the probability of collisions, in the case of constellations, collision avoidance in a dynamic environment is not currently practical. Thus, AMSAT recommends that, if the Commission should conclude it should institute rules regarding orbital debris, it should require in the appropriate portions of 47 C.F.R., that satellites licensed to use the radio spectrum by the FCC, provide full, classical, Keplerian orbital elements for each spacecraft after launch and on a periodic basis thereafter. It further recommends that these element sets be cataloged and made available to the pubic in an easily usable standardized format. It is pointed out that this task is already being carried out by the North American Air

[9] NPRM at §41 to §44 and §47 to §50.

Defense (NORAD). The parameters used, however, employ a format specialized for DoD purposes and the information is not generally made available to the public. This process would be most effective if the information could be made available via an FCC website, or equivalent. It should be the responsibility of each space station licensee to provide this data in a specified form and on a defined periodic basis. The information should then be incorporated into the publicly accessible database which could be cross-checked with NORAD data. Finally on this matter, AMSAT supports the Commission's proposal to continue to allow applicants to select the orbital elements for their space systems, given the existence of the database referenced above.

18. In the Notice at §49 the Commission specifically concludes, "non-geostationary satellite systems should disclose in license applications the tolerance within which orbital parameters would be maintained, so that generally affected third parties can evaluate any collision risk." AMSAT points out that many non-geostationary spacecraft do not include propulsion or any other means of orbit maintenance. Such spacecraft operators can only provide an estimation of how the spacecraft orbital elements might be expected to change with time. Without periodic updates of these elements, tolerances associated with the satellites instant orbit location will continue to increase. Thus, it *would* be economically harmful to many low cost space missions if they were required to provide means to maintain their spacecraft's orbital elements within some tolerance band. Further, as per comment at 17, AMSAT does not believe current means of determining a satellite's position in space and propagating its position into the future are sufficiently accurate to assure avoidance of collision by means *of selection of an initial operating orbit.* In addition, it does not believe the orbits of current spacecraft, even with accurate propulsive means, can be adjusted with sufficient accuracy to avoid collisions with other space objects.

19. In the Notice, the Commission seeks comment on whether it would be appropriate to adopt the post mission guideline or portions of the guideline, as FCC rules. Further, the Commission seeks

comment on technology developments that may affect end-of-life procedures.[10] AMSAT comments on both of these areas by means of offering a consolidated argument. It feels the Commission has correctly recognized the importance of altitude "regimes" in its efforts to deal with orbit debris mitigation. It is of primary importance to recognize that objects at orbit altitudes exceeding 900 km[11] have lifetimes which exceed the time for all practical mission planning and debris evaluation and management methodologies. Though AMSAT does not take specific issue with the NPRM's 25 year rule-of-thumb as a practical limit for the elimination of debris from orbit, or its transfer to suitably established *graveyard* orbits, it feels that it may be practical, in the light of the aforementioned new technology, to require spacecraft with initial orbits below 900 km to limit orbital lifetimes to less than that.

20. Spacecraft having perigees in higher than 900 km and lower than 2000 km are the most problematic. This altitude regime includes the orbits used for some constellation missions and includes some popular polar and sun-synchronous mission orbits.

21. The Commission seeks comment regarding end of life disposal by re-entry, with respect to safety consideration of persons and property on the Earth's surface.[12] AMSAT wishes to point out that most amateur radio satellites have had relatively low masses, and thus could be expected to completely burn up on re-entry. This is not necessarily true of AO-40, but it is in an orbit which has no commercial use and should remain stable for the foreseeable future. Thus, it might be considered to already be in a graveyard orbit.

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[10] NPRM at §54 and §55.

[11] Wertz, J.R. and Larson, W.J., "Space Mission Analysis and Design," Fig. 8-4, Space Technical Library, 1999, p 210. Notice that for an object in a 900 km circular orbit the lifetime of a space object with a ballistic coefficient of 20 Kg/m^2 will re-enter in approximately 110 years. Extrapolation of the information from this figure suggests that if the ballistic coefficient of an object in the same orbit were reduced to approximately 5 Kg/m^2, the lifetime of the space object could be reduced to less than 25 years.

[12] NPRM at §58

22. AMSAT views with particular alarm the Commission's apparent intent expressed with regard to bringing under its Rules spacecraft licensed in other countries when used by entities within the U.S.[13] It is pointed out that U.S. licensed amateurs frequently use amateur satellites licensed in other countries. AMSAT contends that this fact cannot be used to somehow bring these foreign spacecraft under any Rules which might result from this proceeding, or to prevent FCC licensed amateurs from using them, merely because they do not comply with these Rules.

23. With the foregoing in mind, AMSAT believes that the wording the Commission proposes for Part 97.207 of its Rules[14] are generally satisfactory and can be met by builders of amateur radio satellites.[15] However, if the Commission should decide, as inferred in this proceeding, to also include other provisions such as are described elsewhere in the document[16] a cessation of *ALL* U.S. amateur satellite construction and launch activities could well result. Further, if it is interpreted that foreign licensed satellites used by FCC licensed amateurs are covered under rules proposed in this proceeding, all such satellite operation by U.S. amateurs would be ended.

RESPECTFULLY SUBMITTED,

The Radio Amateur Satellite Corporation
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By _____ Date July 17, 2002

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[13] NPRM at §62
[14] NPRM at Appendix B *Proposed Rule Change to 47 C.F.R. Part 97*
[15] Sec. 97.207(g)(1) of the Commission's Rules currently requires the first notification thereunder to be submitted 27 months prior to initiating space station transmissions. Although the present NPRM does not propose to change the 27-month deadline, it has proven to represent a significant burden for amateur radio satellites. This is because launch information is not known that far in advance. AMSAT will be addressing this problem in a separate Petition for Rule Making in the near future.
[16] NPRM at §63